STATUS OF THE ACCIDENT SEQUENCE PRECURSOR (ASP) PROGRAM AND THE STANDARDIZED PLANT ANALYSIS RISK (SPAR) MODEL DEVELOPMENT PROGRAM

ASP Program Status

Analysis of FY 2001–2004 events. During this reporting period, the staff screened and reviewed more than 700 licensee event reports (LERs) from FY 2001–2004 to identify potential precursors. Of the 148 events selected for analysis, the staff completed 119 analyses, rejecting 79 as not meeting the precursor threshold and identifying 40 precursors. With the exception of the ongoing analyses of the condition discovered at the Davis-Besse Nuclear Power Station and the cracks in the control rod drive mechanism (CRDM) housings at several plants, the staff has completed ASP analyses for all events that occurred in Fiscal Years (FYs) 2000–2002. The analyses of FY 2003 events are also nearing completion, and the analyses of FY 2004 events have begun. Attachment 2 to this paper summarizes the final and preliminary precursor analyses, and provides a list of events involving CRDM cracking.

Davis-Besse. The condition discovered at the Davis-Besse Nuclear Power Station involved degradation of the reactor vessel head and cracking of the CRDM housing. The related precursor analysis also takes into account the simultaneous existence of unqualified coatings and other debris that could plug the containment sump, as well as a design deficiency in the high-pressure injection pumps. The Office of Nuclear Regulatory Research (RES) has completed a project to use the laboratory characterization of the degraded vessel head material and analytic models to estimate the probability of a loss-of-coolant accident from the vessel head degradation. Preliminary ASP analysis results show that this event is potentially a significant precursor. The staff issued the preliminary ASP analysis for peer review in September 2004.

CRDM cracking events. The staff is currently analyzing conditions involving primary water stress corrosion cracking of CRDM housings. The events reviewed during this reporting period involved the discovery of such cracks at 11 plants in FYs 2001–2003 and may result in 11 precursors. This ongoing analysis involves completing the RES probabilistic analysis of the time-dependent failure frequencies of the CRDM housings. The staff is currently analyzing these potential precursors in conjunction with characterizing the probability of failure of the as-found crack conditions at Davis-Besse. In addition, the staff has conducted a sensitivity analysis to show that CRDM cracking events at plants other than Davis-Besse would most likely not cause an event to be classified as a significant precursor (i.e., CCDP $\geq 1 \times 10^{-3}$), but would most likely be classified as a precursor (i.e., CCDP $\geq 1 \times 10^{-6}$). The staff will issue its preliminary analyses of the remaining plants for peer review following the completion of the final Davis-Besse analysis.

Implementation of the ASP catchup plan. The staff plans to complete its FY 2003 analysis of potential precursors by December 2004, while proceeding to analyze FY 2004 events. In addition, to improve the timeliness of the analyses of potentially high-risk events, the agency is redirecting resources to those analyses when such events are identified during NRC inspections or in LERs. For example, collaboration with the regional office enabled the staff to complete its preliminary ASP analysis of the June 2004 Palo Verde loss of offsite power in less than 2 months. As a result, the staff subsequently included the results of that analysis in the

Region IV augmented inspection team (AIT) report. Similarly, within 4 months following the issuance of LERs regarding the eight loss of offsite power events caused by the electrical grid blackout in August 2003, the staff completed its analyses of all eight related precursors. These results were used as input to the Agency's grid reliability Action Plan.

Investigation of trends and engineering insights. Attachment 2 presents trends and general insights that emerged from the staff's analysis of the ASP data. In FY 2005, the staff will initiate a detailed evaluation of the ASP data to investigate the nature of trends, determine whether there is an explanation for the relatively low number of precursors between 1997 and 1998 and the increasing number of potential precursors in 2000–2002, and identify any engineering insights that can be applied in the NRC's regulatory programs. This collaborative effort, which will be initiated in response to a recommendation from the Operating Experience Task Force, will draw upon the broad expertise of staff throughout the agency.

ASP Program Improvements and Activities

To improve efficiencies in the ASP Program, the staff has initiated programs to streamline the ASP analysis and review processes, and standardize the risk assessment of operating events within the agency. (Subsequent sections of this attachment provide additional detail concerning these and other improvements.) The goal of the ASP Program is to complete the analysis of potential precursors within 4–12 months following the initiation of an event or discovery of a condition. However, the staff recognizes that additional time may be required to complete the analysis of the occasional complex, first-of-its-kind event that requires the development of new models or methods. Historically, the staff has encountered about two complex analyses per year.

Streamlining of analyses and reviews. As previously noted, the staff has attempted to increase efficiency by initiating an effort to streamline the ASP analysis and review processes. Specifically, the staff has implemented a strategy to prioritize and, where appropriate, scale back efforts on noncontroversial events and those with lower CCDPs. That strategy uses a graded approach to methods, documentation, and peer review of ASP analyses. The graded approach will improve efficiencies in analyzing events for potential precursors by reducing duplicative analysis of events, the burden on licensees, and repetitive peer reviews. This approach includes the following measures:

- For ASP analyses of noncontroversial, low-risk precursors in which the ASP results reasonably agree with the SDP results, detailed uncertainty analyses and formal peer reviews by staff and the licensee will not be performed. The ASP Program will continue the in-house review process for all analyses.

- In lieu of a detailed ASP analysis of a condition in which the SPAR model was used in an SDP Phase 3 analysis, RES will perform a comprehensive technical review of the final SDP Phase 3 analysis for green, white, or yellow findings.

- RES resources will be optimized to focus on events with the highest risk significance. An ASP analysis of a potentially significant precursor (i.e., CCDP $\geq 1 \times 10^{-3}$) will be started immediately after being identified during an NRC inspection or documented in an LER.

The graded approach has had a noticeable effect in streamlining the ASP Program. In the last 18 months, about 70 percent of the ASP precursor analyses that included noncontroversial, low-risk events and reasonably agreed with the SDP results did not require time for additional peer reviews. The elimination of these reviews reduced the time to complete final precursor analyses by four to five months. In addition, since these events were analyzed by the SDP, the graded approach eliminated the burden on licensees, as well as staff, having to perform additional peer reviews.

Methods improvements. The development of new and enhanced analytical methods is an important part of the ASP analysis process. Methods used in routine analyses are improved where needed, while new methods are developed for the analysis of complex, first-of-its-kind events. As a result, the methods used in analysis today are more sophisticated than those used in the past.

In the past, the ASP Program included a category called "Potentially Significant Events Considered Impractical to Analyze." That category was used to bin potential precursors that were difficult to analyze because of a lack of information or an inability to reasonably model the event within a PRA framework, considering the level of detail typically available in PRA models and the resources available to the ASP Program. About 25 percent of the events in the ASP database for the period from 1969 through 1994 were considered impractical to analyze. By contrast, only two events since 1995 were similarly binned.

In the current program, the staff obtains information needed to analyze complex events using more elaborate methods, such as plant visits, inputs from the inspection program, use of an informal expert elicitation process, development of new analysis methods, enhancement of existing SPAR models, and use of sensitivity or uncertainty analyses.

During the current reporting period, the following methods were developed or are currently under development:

- *Uncertainty analysis.* Parameter and modeling uncertainties were first included in the ASP analysis of the D.C. Cook (2001) and the Point Beach (2002) precursors. The parameter values for equipment performance and human performance used in the risk model and the uncertainties regarding these values (*parameter uncertainty*) are estimated using generic industry data adjusted for plant-specific operating experience and design features. These data and uncertainty distributions are then propagated through the SPAR model to produce a mean value of the CDP as well as the 5^{th} and 95^{th} percentile values. The issue of alternative model assumptions (often referred to as *model uncertainty*) is handled by performing sensitivity studies.

- *Human Reliability Analysis (HRA).* The ASP Program uses the SPAR HRA methodology to estimate human error probabilities for recovery actions. The HRA methodology report was issued for peer review in Fall 2003, and the Advisory Committee on Reactor Safeguards (ACRS) was briefed on the new method in October 2003. In addition to discussing the method and models, the report presents definitions and guidance for use in applying the model in ASP and SDP analyses. The final report (which will incorporate peer review comments) will be issued during the first quarter of FY 2005.

- *ASP expert elicitation process.* In 2003, the staff initiated a project to develop a simplified, limited expert elicitation methodology and procedure to meet the needs of the ASP Program. This procedure will formalize the process used to determine the probability of failure and the operability of equipment for events or conditions that are rare or for which insufficient operational data exist to make meaningful estimates. The new process will involve a formal procedure for seeking expert opinion and judgment that follows the existing expert elicitation methodology, but is simplified and streamlined as appropriate to the required degree of accuracy and the schedule for completing the ASP analyses. The staff plans to issue the procedure for peer review early in FY 2005.

The use of these new methods has proven to be effective in reducing the time needed to complete precursor analyses. Uncertainty analysis has reduced the need for supplemental information from regional staff and licensees for those cases where sensitivity analysis shows an uncertain assumption is not an important contributor to the overall risk. In addition, uncertainty analysis has been used as a measure of reasonableness when comparing ASP and SDP results.

National Academy of Engineering report on precursor programs. On August 18, 2004, the National Academy of Engineering (NAE) released a report, entitled "Accident Precursor Analysis and Management, Reducing Technological Risk Through Diligence." That report documents the 7-month Accident Precursors Project, which reviewed approaches for detecting, analyzing, and benefitting from accident precursors. The NAE invited the NRC to participate in the project because of the agency's recognized leadership in accident precursor analysis, as demonstrated by the ASP Program. The NAE report contains 11 general recommendations intended to enhance the use of accident precursor data. It also reinforces the potential value of precursor analysis and the use of its results and insights in the regulatory program, consistent with the findings of the NRC's Operating Experience Task Force. In addition, the NAE report recognizes the ASP Program as an example of a precursor program that is worthy of emulation by other Government agencies.

ASP database on the agency's Intranet. The staff has upgraded its database of ASP analysis results and reports, which currently contains the final analysis results of more than 600 precursors identified by the ASP Program since 1969. Beta testing of the upgraded ASP database was completed in 2003, and the database is now available to the NRC staff through the RES Reactor Operating Experience Results and Databases internal Web page. However, given the sensitivity of information contained in the analysis reports, the agency will not make this database available through the NRC's public Web site at this time.

Communications with external organizations. In addition to a presentation at the NAE workshop on precursor programs in August 2003, NRC staff representatives provided presentations and inputs concerning ASP program status and results to numerous organizations. In particular, these included presentations at the Sixth Technical Meeting on Experience with Risk-Based Precursor Analysis held in Brussels, Belgium (November 2003); the ACRS Subcommittee on Reliability and Probabilistic Risk Assessment (March 2004); the Massachusetts Institute of Technology summer session on reactor safety (June 2003 and 2004); the National Aeronautics and Space Administration, Office of Safety and Mission Assurance (July 2004); and the Atomic Energy Regulatory Board of India (September 2004). In addition, staff representatives provided input to the annual Commission paper on the NRC's

Industry Trends Program (SECY-04-0052) and the U.S. National Report to the Convention on Nuclear Safety (soon to be published as a NUREG-series report).

SPAR Model Development

The SPAR Model Development Program has played an integral role in the ASP analysis of operating events and has evolved over three generations into detailed tools for the analysis of internal events during full-power operations. New SPAR models are currently being developed in response to staff needs for modeling internal initiating events during low-power and shutdown (LP/SD) operations, external initiating events, and large early release frequency (LERF).

The SPAR Model Users Group (SMUG) is composed of representatives from each organization within the agency's program and regional offices that use risk models in their regulatory activities. The SMUG meets regularly to provide technical guidance for the SPAR Model Development Program, consistent with the approved Integrated SPAR Model Development Plan. In accordance with that plan, which conforms to the modeling needs that the SMUG members and their management identified for performing risk-informed regulatory activities, the staff completed the following activities in model and method development since the last report:

SPAR models for analysis of internal initiating events during full-power operation

- Completed the onsite quality assurance (QA) review of the last 19 Revision 3i SPAR models, in conjunction with benchmarking of the SDP Plant Notebooks by the Office of Nuclear Reactor Regulation (NRR). This effort involved reviewing the SPAR model with the licensee's PRA staff and benchmarking that model against the licensee's PRA. With this achievement, all 72 Revision 3i models have undergone onsite QA review, the models and their accompanying documentation have been revised to reflect the review results, and they have been certified as Revision 3 models.

- Completed the detailed review of the Revision 3 SPAR models for the 11 pilot plants participating in the Mitigating Systems Performance Index (MSPI) Program, and modified the SPAR models for those plants to reflect the review results.

- Using the insights obtained from the review of the pilot plants in the MSPI Development Program, developed a strategy for a similar type of review (down to the cut set level) and subsequent model revision that will produce a set of enhanced Revision 3 SPAR models. This effort will also require resolution of a number of PRA modeling issues that were identified (1) during the onsite QA reviews of the Revision 3 SPAR models; (2) during the MSPI pilot program reviews; and (3) from feedback by model users. The staff is currently developing proposed strategies for resolving these modeling issues with the industry.

SPAR models for analysis of internal initiating events during low-power and shutdown (LP/SD) operation

- Completed interim LP/SD SPAR models for Diablo Canyon Nuclear Power Plant, Palo Verde Nuclear Generating Station, Oconee Nuclear Station, Peach Bottom Atomic Power Station, River Bend Station, and Grand Gulf Nuclear Station, and sent the models to the respective licensees for review. The staff has now completed 10 LP/SD SPAR models, and this marks the completion of the first phase of the effort. The second phase consists of an onsite QA review of the models.

- Conducted onsite QA reviews of the LP/SD SPAR models for Peach Bottom, River Bend, and Grand Gulf. The staff will schedule onsite reviews for the remaining plants in FY 2005.

- Met with the ACRS to discuss development of LP/SD SPAR models. The Committee provided favorable comments and asked the staff to keep the ACRS informed about the progress of this model development effort.

SPAR models for the calculation of large early release frequency (LERF)

- Completed the LERF SPAR model for Comanche Peak Steam Electrical Station (the lead plant in the first plant class), which is a 4-loop Westinghouse-designed pressurized-water reactor (PWR) with a large, dry containment. The staff subsequently sent the model to the licensee in the course of preparing for the onsite QA review of the model against the licensee's Level 2/LERF model.

- Completed the preliminary model for Peach Bottom Atomic Power Station (the lead plant in the second plant class), which is a boiling-water reactor (BWR) 3/4 with Mark I containments. The staff subsequently sent the model to key NRC users for internal review.

SPAR models for the analysis of external events

- Started work in July 2004 to incorporate external initiating events (i.e., fires, floods, and seismic sequences) into the Revision 3 SPAR models. This effort is part of the Risk Assessment Standardization Project (RASP) in support of ASP and SDP Phase 3 analyses. Development is being performed in conjunction with NRR's SDP external events Phase 2 worksheet benchmarking program.

- Completed plant visits to Diablo Canyon, Limerick Generating Station, and Salem Generating Station to gather plant-specific information and data for a feasibility study. The staff expects to complete this feasibility study early in FY 2005.

Risk Assessment Standardization Project (RASP)

Risk assessments of reactor events and conditions, which are performed by several groups within the NRC, require the benefit of standard procedures, methods, models, and formats. Such standards would enable the staff to avoid duplication of effort, inconsistent products, and conflicting results. Detailed documentation of analysis procedures and methods would also reduce the time required to complete routine risk analyses of operating events and licensee performance issues. In addition, improved documentation would enhance the internal and external communication of risk results.

Background. NRR asked the RES staff to develop procedures and methods that RES, NRR, and the regional offices will use to achieve more consistent results when performing risk assessments of operating events and licensee performance issues. The project will draw upon the expertise developed in the ASP Program to document risk assessment guidelines.

As envisioned, the RASP will promote consistency in the methods and formats used for the agency's risk assessments. The primary focus of this project is to standardize risk analyses in

SDP Phase 3, the ASP Program, and the Incident Investigation Program under Management Directive (MD) 8.3.

Under this project, the NRC staff will complete the following activities:

- Develop guidelines for analyses of internal events during power operations.

- Develop consistent methods and guidelines for SDP Phase 3, ASP, and MD 8.3 analyses of internal fires and floods, external events (e.g., seismic events and tornadoes), internal events during LP/SD operations, and LERF sequences.

- Enhance SPAR models and the suite of codes used to manipulate those models (i.e., the SAPHIRE PRA code and GEM interface code).

- Provide on-call technical support to NRR and regional senior reactor analysts. This support will include developing analysis methods or refining existing methods, making analysis-specific enhancements to the SPAR models, and supporting SDP Phase 3 analyses on an as-requested basis.

This effort will support the ASP Program's long-term plan to improve the efficiency of ASP analyses and to increase consistency between ASP approaches and those used in SDP analyses, where possible. In addition, this effort is part of NRR's SDP improvement initiative.

Status. The NRC formed the RASP Coordination Team to oversee the development and implementation efforts. The team includes representatives from the RES Operating Experience Risk Analysis Branch (OERAB), the NRR Probabilistic Safety Assessment Branch (SPSB) and Inspection Program Branch (IIPB), and the regional offices. To date, the RASP Coordination Team has identified preliminary deliverables, operating plan milestones, and a schedule.

The staff began working on the internal event guidelines in April 2004, and has identified the scope, level of effort, and schedule for guidelines to address external events, LP/SD operations, and LERF. The effort will directly follow completion of the internal events analysis guidelines. A preliminary completion date for all guidelines is mid-2006.